Fall 2007

CrosSection: An Exploration into Assembling Sustainability

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CROS$ECTION

AN EXPLORATION INTO ASSEMBLING SUSTAINABILITY

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Thesis Fall 2007

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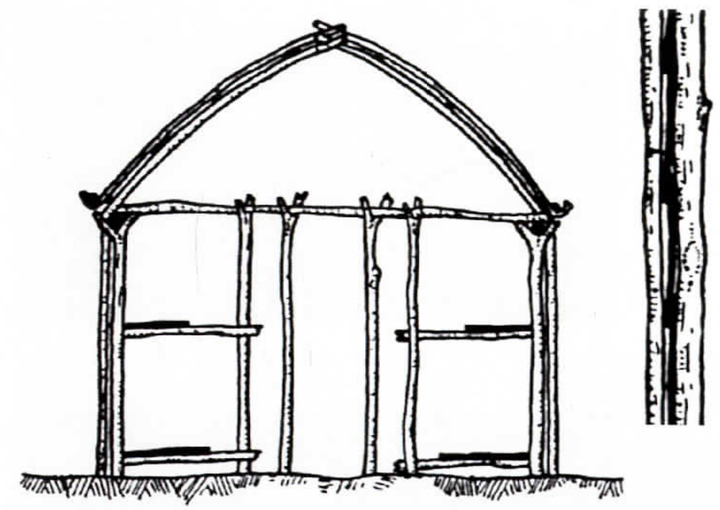
Contention

The field of architecture sits at a crossroads today, we have an opportunity to rethink the way we design using new materials and building techniques to reduce the negative impact architecture has on the wider environment. As architects, we must critically look at our constructions methods and question whether they are appropriate and the best choices we could be making for the environment. My thesis has generated a framework that used a set of sustainable materials that outperform their conventional alternatives, to produce affordable and highly efficiently built homes that leave a neutral impact on the environment.

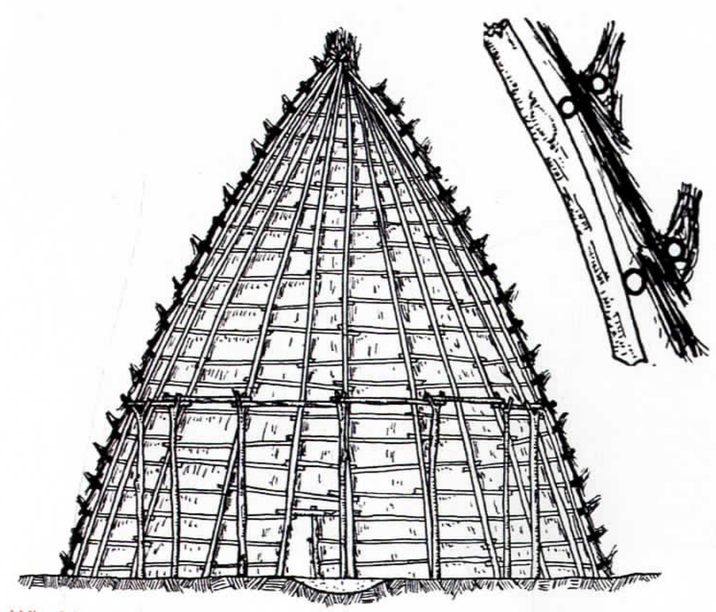
Las Vegas, Nevada

The Paradigm Shift

Vernacular building largely was a response to materials at hand and their ability to mediate between the interior and the outside environment. Therefore, climate largely dictated the material used for building based on their envelope performance. Climate specific vernacular building has steadily been replaced by industrial innovation. The paradigm shift that ensued in the early 20th century dematerialized the envelope, and its thermal performance has been replaced with resource draining mechanical systems.

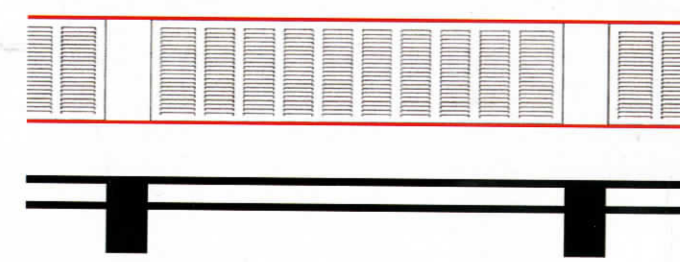


Long House



Witchita Grass House

Seagram Building



Building Envelop 3" | Climate Control 12"

Loss Of Vernacular

As we look at the residential landscape today across America the loss of the local vernacular becomes vividly apparent. Largely one solution is implemented for all conditions. Whether in northern Wisconsin or South Carolina, it is virtually impossible to find differences in the materials and methods of construction even though their climates vary dramatically.

Which house belongs in each city?

A

B

C

D

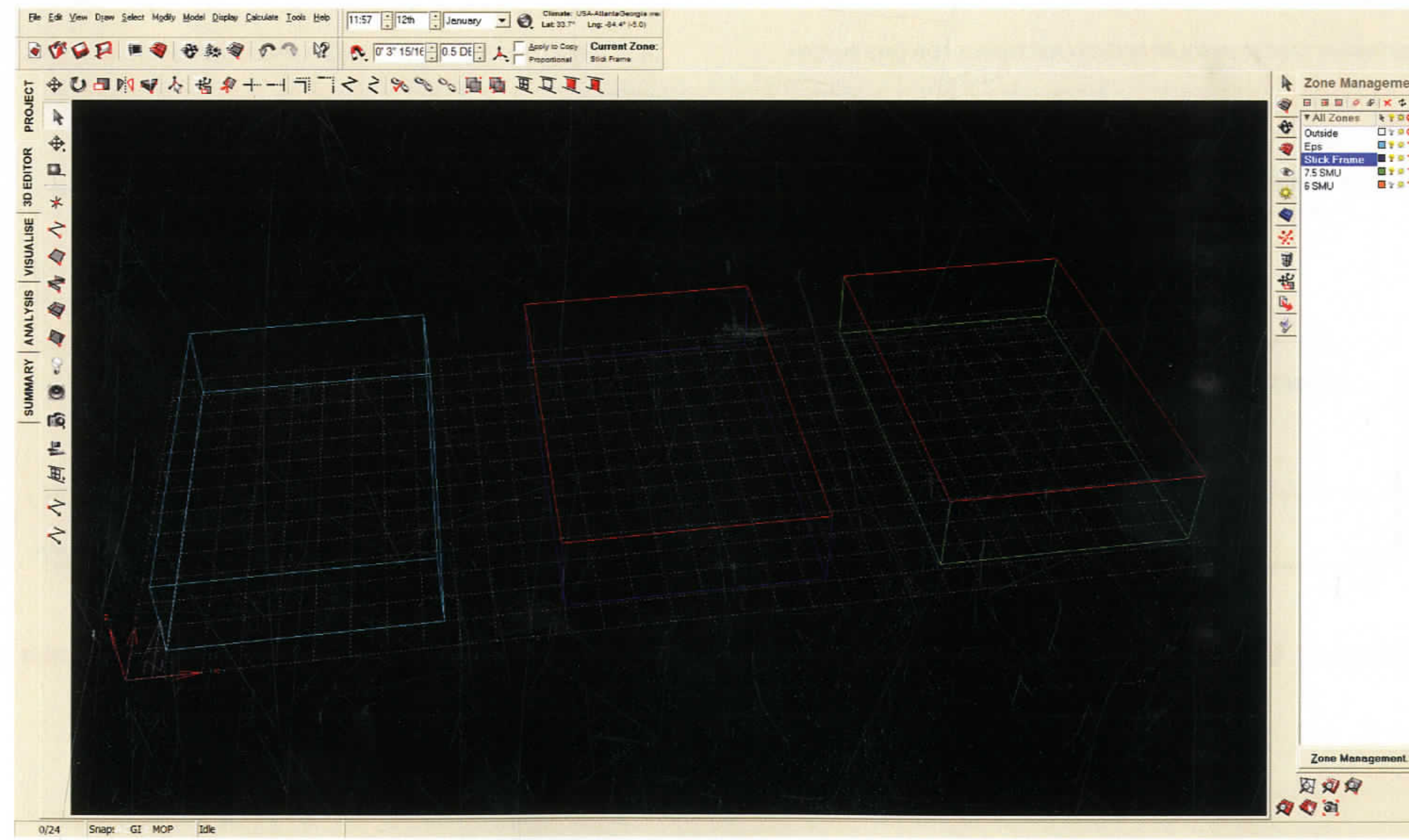
Material | Assembly Analysis

Designing a new assembly from sustainable materials required a critical examination of conventional materials and their performance characteristics. This in depth analysis allowed me to compare conventional assembly construction with speculative sustainable alternatives. In order to objectively compare each based on thermal performance I used the software *Ecotect* to run environmental simulations.

Material	Width	Density	Sp. Heat	Conductivity
Plastics				
Vinyl Siding	*3/4*	*0.75*	*0.2*	*10*
Vinyl Siding Insulated	*3/4*	*1.9*	*0.5*	*0.25*
Wood Plastic Composite	*1 3/8*	*62.4*	*0.55*	*0.3333*
Masonry				
Brick Fire Clay	4 5/16	123.61	0.31749	0.749
Clay Tiles	3/8	118.61	0.35114	0.549
Rammed Earth	19 1/2	162.31	0.41371	0.531
Brick	4 5/16	124.86	0.35976	0.411
Concrete Cinder Block	8	99.88	0.28242	0.193
Gypsum Plasbrd	3/8	68.67	0.36114	0.376
Plaster	3/8	74.91	0.36114	0.3
Stucco	*7/8*	*50*	*0.5*	*0.2*

Material	Width	Density	Sp. Heat	Conductivity
Wood Organics				
Vegetable Fib Sheat.	3/8	18.1	0.5589	0.032
Sawdust	3/8	11.86	0.42992	0.029
Particle Board	3/8	49.94	0.5589	0.069
Cork	3/8	6.87	0.77386	0.023
Plywood	3/8	43.7	0.61049	0.087
White Pine	1	33.09	0.98925	0.075
OSB	*7/16*	*40*	*0.68*	*0.51*
Strawboard	*2 1/4*	*26.21*	*0.5589*	*0.56161*
Homasote	*3/4*	*27*	*0.90284*	*0.714285*
Wheatboard	*3/4*	*70*	*0.75*	*0.25*
Durra Board	*2*	*26.21*	*0.75*	*0.30769*
Insulations				
Fibre Straw Insulation	3/8	18.73	0.90284	0.049
Fibreboard	3/8	14.98	0.32674	0.024
Polystyrene Foam (Low Der	1 15/16	2.87	0.48581	0.019
Polyisosanurate Board	3/8	2	0.39553	0.012
Rockwool	3/8	12.49	0.30525	0.02
Strawboard	3/8	19.35	0.5589	0.033
Straw Thatch	3/8	14.98	0.07739	0.04
Expanded Polystyrene	3/8	1.44	0.63199	0.02
Extruded Polystyrene	3/8	2.18	0.63199	0.016
Cellulose Loose Fill	3/8	2.68	0.59329	0.024
Biofoam Spray	*3 1/2*	*5.333*	*0.5*	*0.0625*
Fiberglass Batt R 13	*3 1/2*	*2.5*	*0.54*	*0.07692*

Cataloguing of Material Thermodynamic Properties



Ecotect Thermodynamic Model

Assembly Thermal Performance

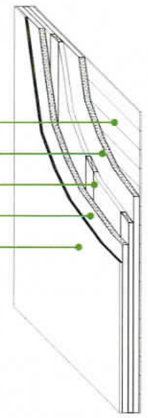
v 1.2

comparative analysis of an unconditioned 1000 SF space

sustainable assembly

SAMPLE | DURRA WALL

Material Layer	Width	Density	Sp. Heat	Cond.
Wood Plastic Composite Siding	1.375"	62.40	.555	0.333
Dura Agripanel	2"	26.21	.750	0.308
Air Gap | Wood Stud	1.5"	0.08	.431	3.213
Durra Agripanel	2"	26.21	.750	0.308
Wheatboard Interior Panel	.75"	40.00	.796	0.250



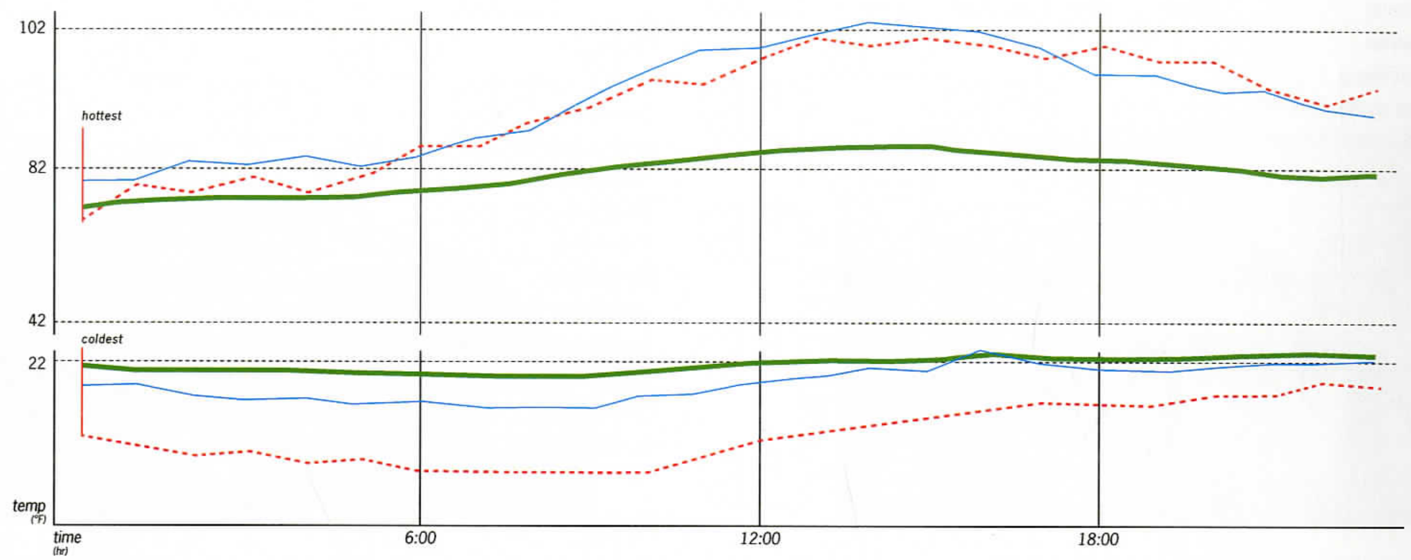
conventional assembly

CONTROL SAMPLE | STICK FRAME

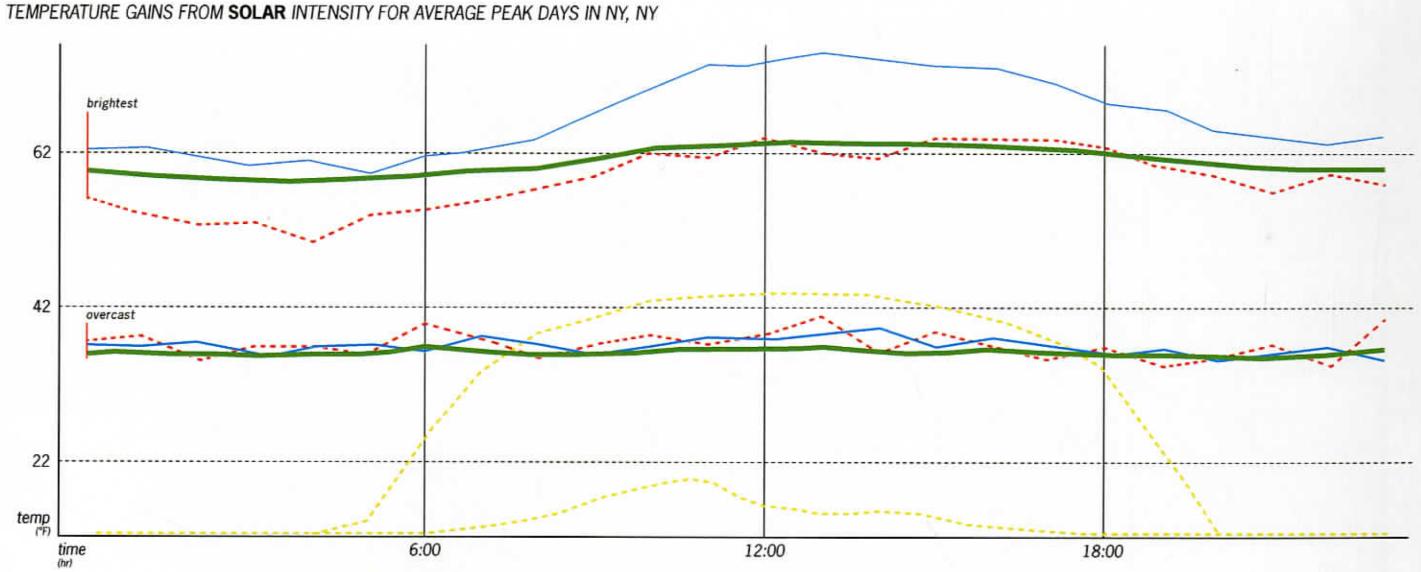
Material Layer	Width	Density	Sp. Heat	Cond.
Wood Pine Siding	.5625"	34.43	.989	.198
Plywood	.375"	43.70	.614	.087
Fiberglass Batt R 13 | Wood Stud	3.5"	2.50	.540	.077
Gypsum Plaster Board	.375"	68.67	.361	.376

TEMPERATURE GAINS FOR AVERAGE **HOTTEST|COLDEST** DAY IN NY, NY

sample — exterior temp — key — control — solar intensity



TEMPERATURE GAINS FROM **SOLAR** INTENSITY FOR AVERAGE PEAK DAYS IN NY, NY



durra wall OUTPERFORMS conventional stick frame construction under both thermal and solar extremes

Assembly Thermal Performance

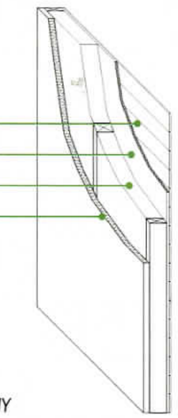
v 2.2

comparative analysis of an unconditioned 1000 SF space

sustainable assembly

SAMPLE | 2x6 CELLULOSE

Material Layer	Width	Density	Sp. Heat	Cond.
Wood Plastic Composite Siding	1.375"	62.40	.550	.333
Homasote 440	.75"	27.00	.900	.714
Cellulose Loose Fill | 2 x 6 Stud	5.5"	2.68	.593	.024
Durra Agripanel	2"	26.21	.750	.308



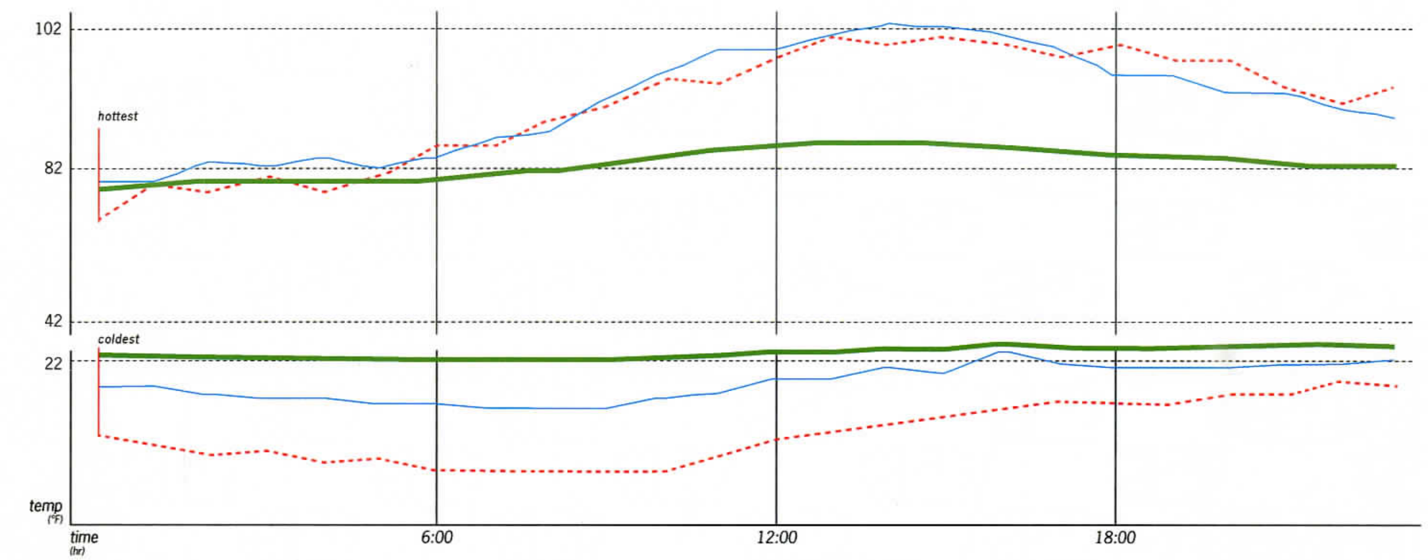
conventional assembly

CONTROL SAMPLE | STICK FRAME

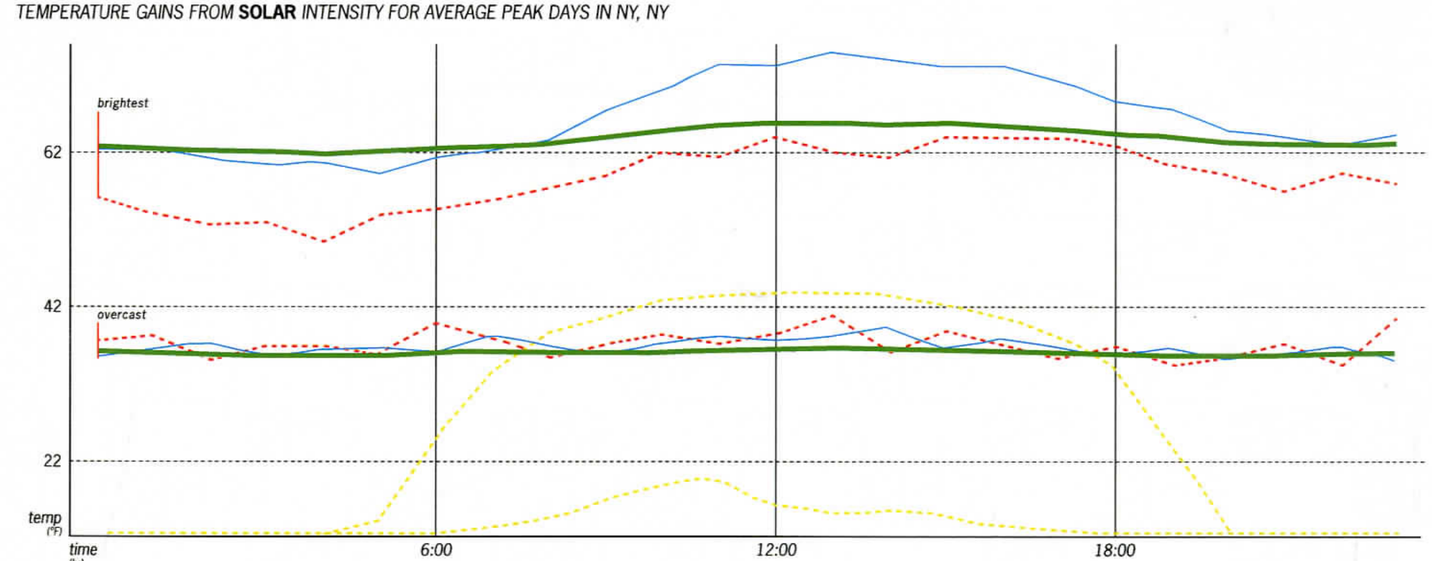
Material Layer	Width	Density	Sp. Heat	Cond.
Wood Pine Siding	.5625"	34.43	.989	.198
Plywood	.375"	43.70	.614	.087
Fiberglass Batt R 13 | Wood Stud	3.5"	2.50	.540	.077
Gypsum Plasterboard	.375"	68.67	.361	.376

TEMPERATURE GAINS FOR AVERAGE **HOTTEST|COLDEST** DAY IN NY, NY

sample — exterior temp — key — control — solar intensity



TEMPERATURE GAINS FROM **SOLAR** INTENSITY FOR AVERAGE PEAK DAYS IN NY, NY



cellulose filled 2 x 6 OUTPERFORMS conventional fiberglass stick frame under the sample conditions

Assembly Thermal Performance

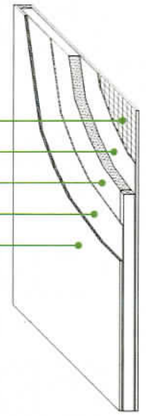
v 3.2

comparative analysis of an unconditioned 1000 SF space

sustainable assembly

SAMPLE | *AGRIPANEL*

Material Layer	Width	Density	Sp. Heat	Cond.
Stucco	.875"	50.00	.550	.200
OSB	.625"	49.70	.610	.092
Agriboard Core	3.5"	15.35	.558	.077
OSB	.625"	49.70	.610	.092
Homasote 440	.75"	27.00	.900	.714



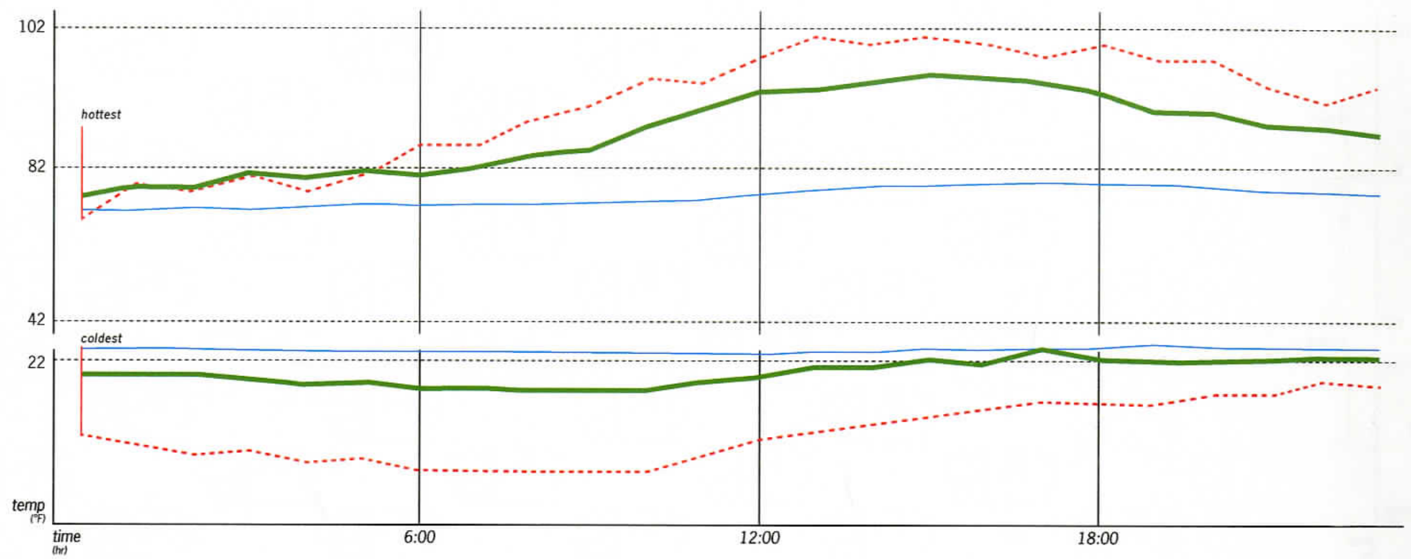
conventional assembly

CONTROL SAMPLE | *BRICK STICK FRAME*

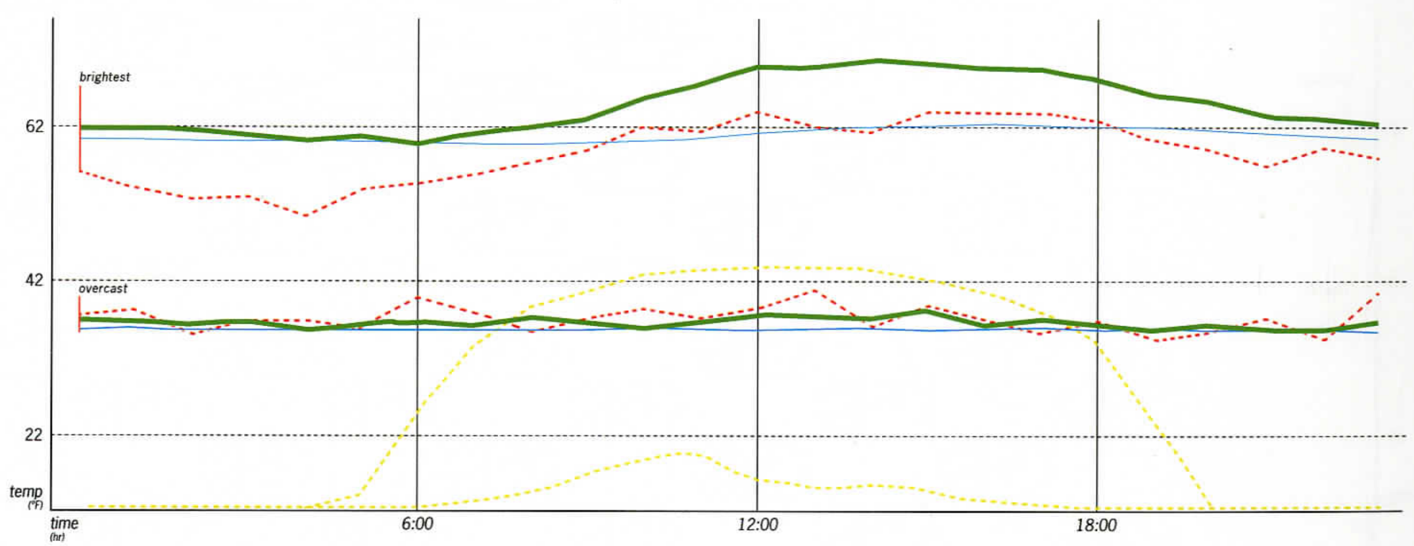
Material Layer	Width	Density	Sp. Heat	Cond.
Brick Masonry	4.3125"	124.86	.411	.411
Polyisosanurate Board	.375"	2.80	.012	.012
Air Gap | Wood Stud	3.5"	0.08	.431	3.213
Gypsum Plasterboard	.375"	68.67	.249	0.249

TEMPERATURE GAINS FOR AVERAGE **HOTTEST | COLDEST** DAY IN NY, NY

sample — exterior temp — key — control — solar intensity



TEMPERATURE GAINS FROM **SOLAR** INTENSITY FOR AVERAGE PEAK DAYS IN NY, NY



agripanel performs slightly better than conventional brick stick frame backup

Assembly Thermal Performance

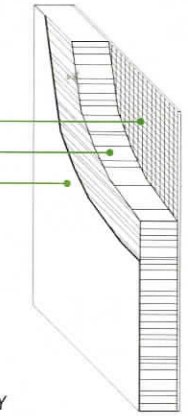
v 4.2

comparative analysis of an unconditioned 1000 SF space

sustainable assembly

SAMPLE | *RAMMED EARTH*

Material Layer	Width	Density	Sp. Heat	Cond.
Stucco | Wire Mesh	1.375"	50.00	.355	.200
Sandstone Rammed Earth	11.75"	162.31	.417	24.175
Plaster	.375"	74.91	.361	.300



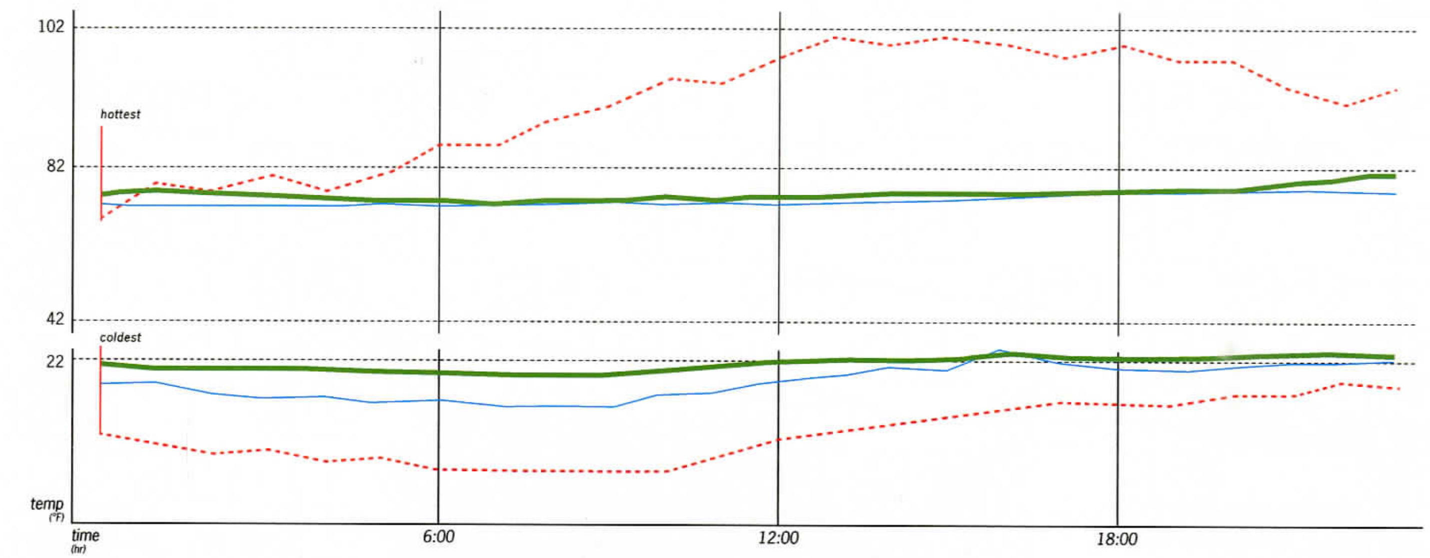
conventional assembly

CONTROL SAMPLE | *BRICK CONCRETE BACKUP*

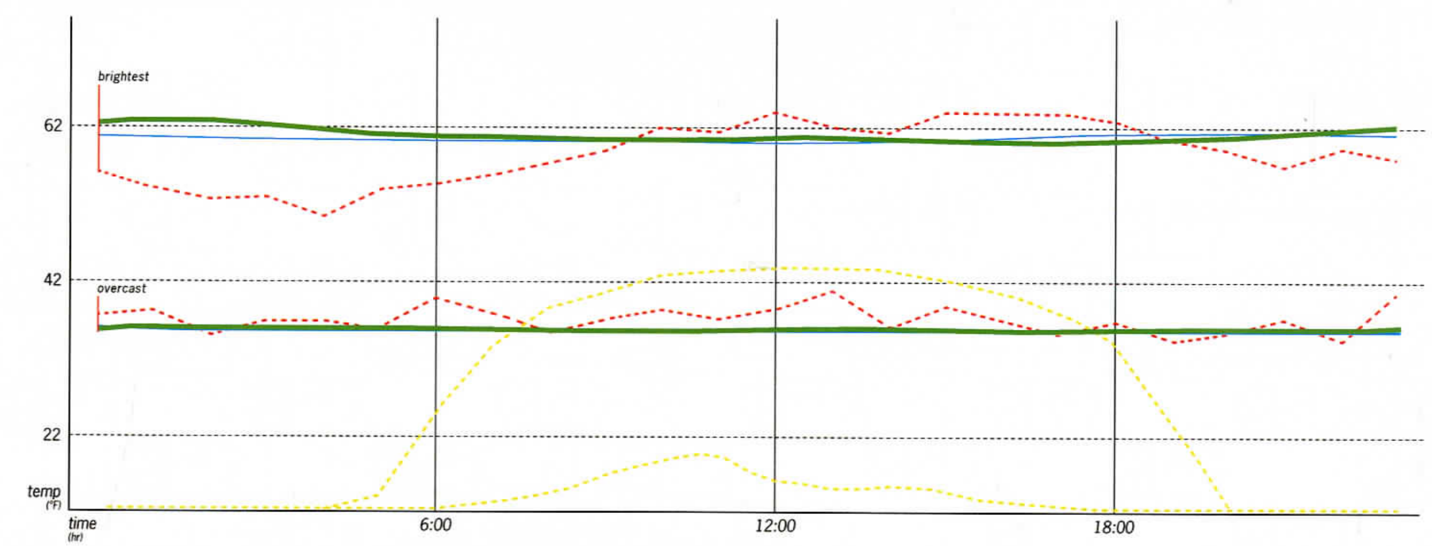
Material Layer	Width	Density	Sp. Heat	Cond.
Brick Masonry	4.3125"	128.86	.359	.411
Concrete Masonry Unit	7.625"	99.88	.282	.193
Plasterboard	.375"	78.03	.467	.249

TEMPERATURE GAINS FOR AVERAGE **HOTTEST | COLDEST** DAY IN NY, NY

sample — exterior temp — key — control — solar intensity



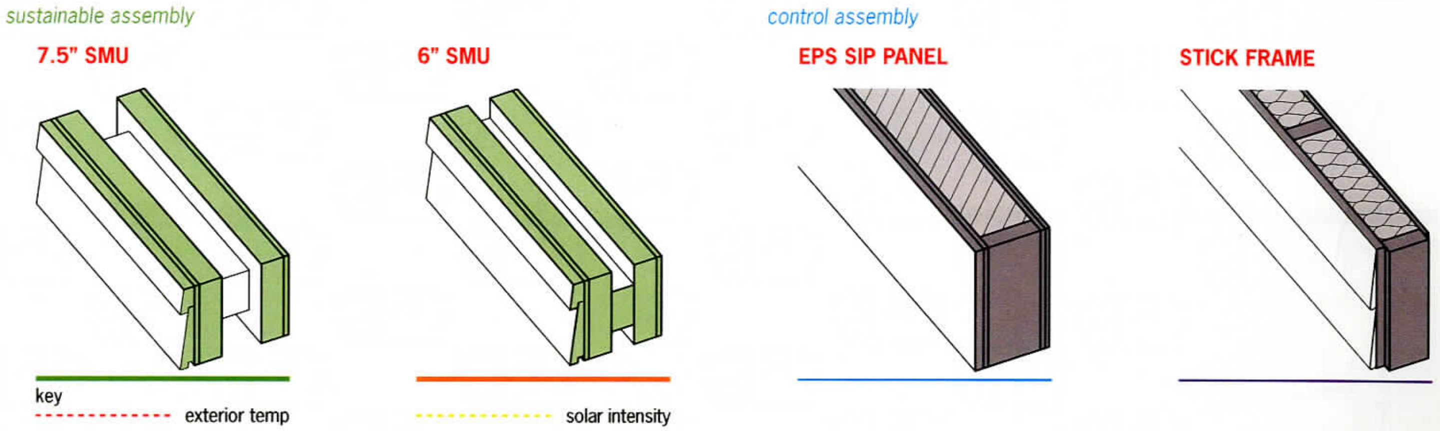
TEMPERATURE GAINS FROM **SOLAR** INTENSITY FOR AVERAGE PEAK DAYS IN NY, NY



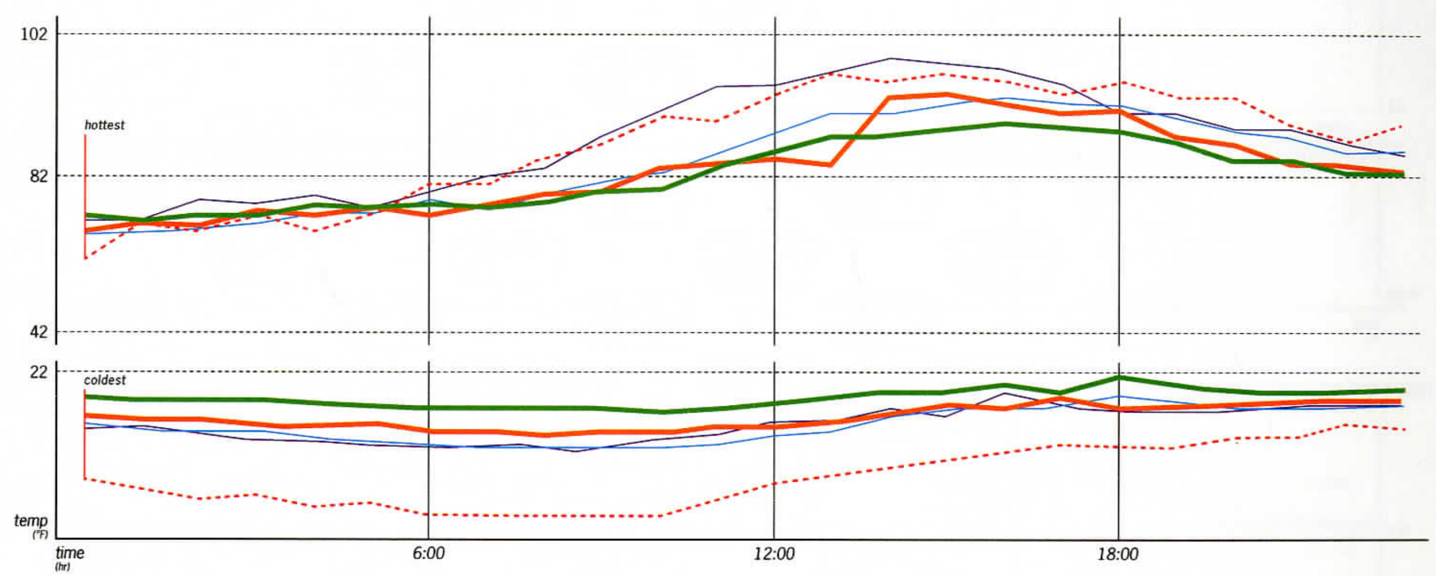
rammed earth performance is equivalent to conventional brick concrete backup under the sample conditions

Assembly Thermal Performance

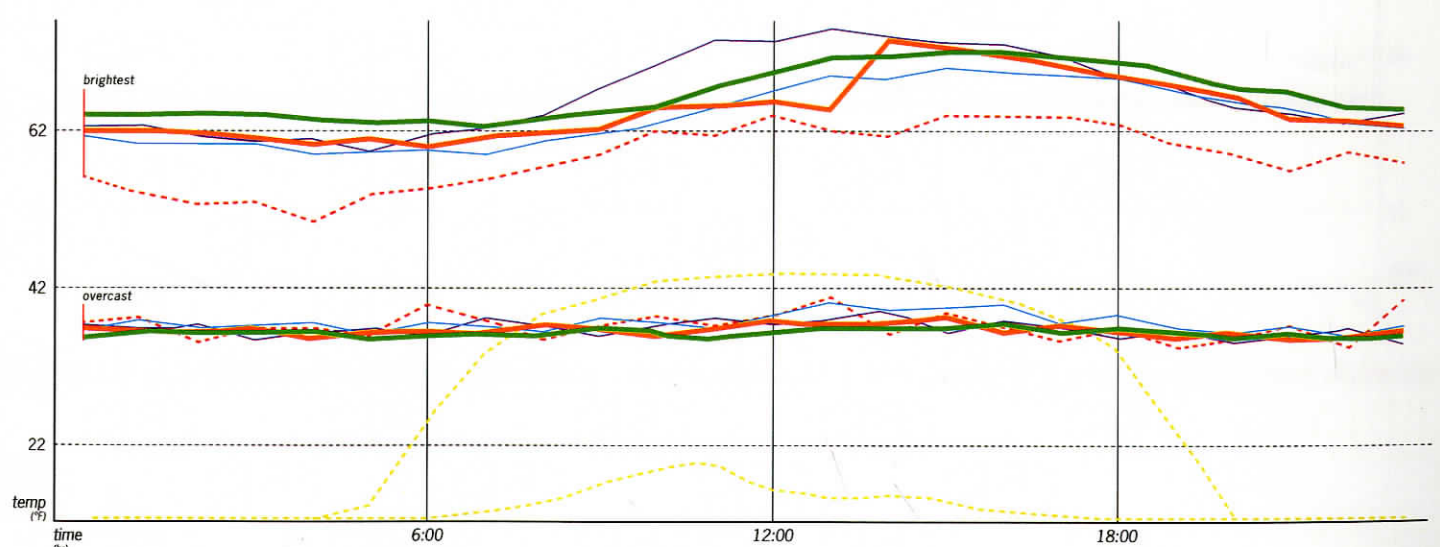
The material I chose to investigate further based on its excellent thermal performance was the straw core assembly. Under the same modeling parameters I was able to determine the minimum thickness a wall composed from the straw core would have to be to perform as well as or better than conventional stick frame and eps sip panels.



TEMPERATURE GAINS FOR AVERAGE **HOTTEST**|**COLDEST** DAY IN NY, NY

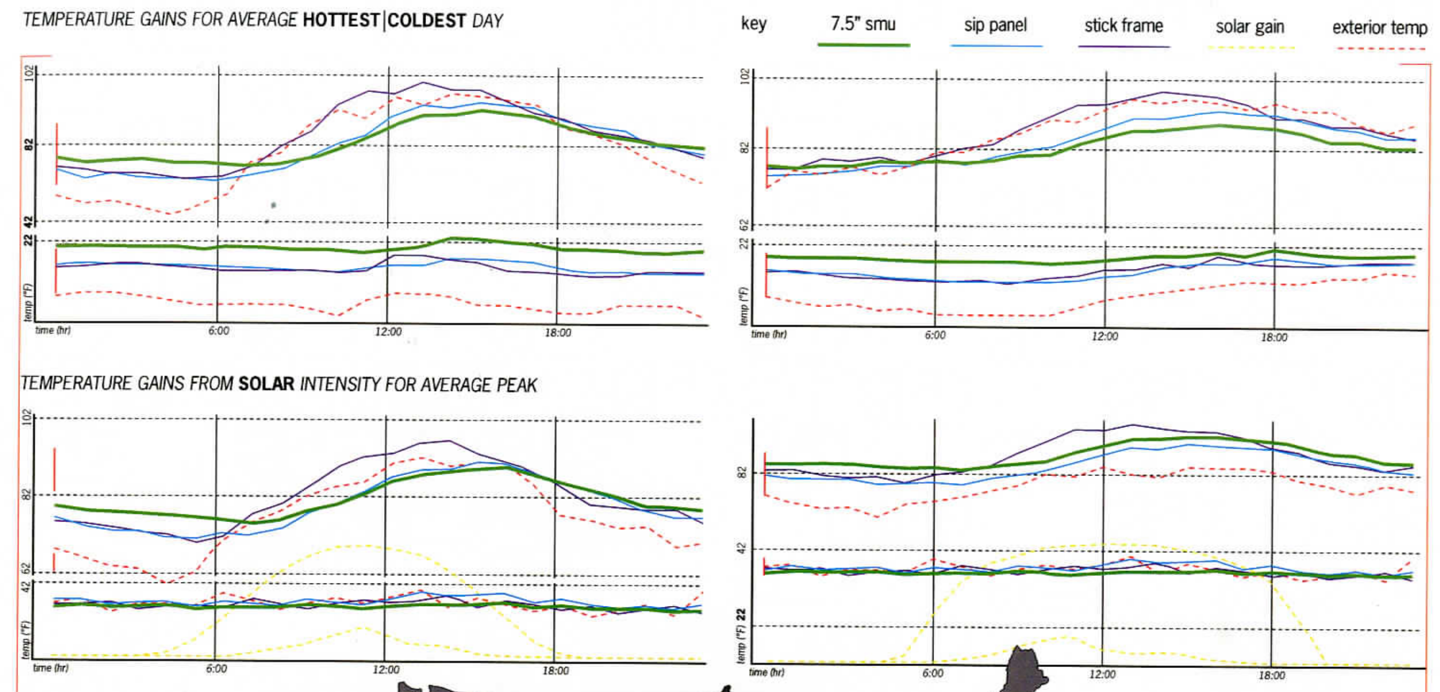


TEMPERATURE GAINS FROM **SOLAR** INTENSITY FOR AVERAGE PEAK DAYS IN NY, NY



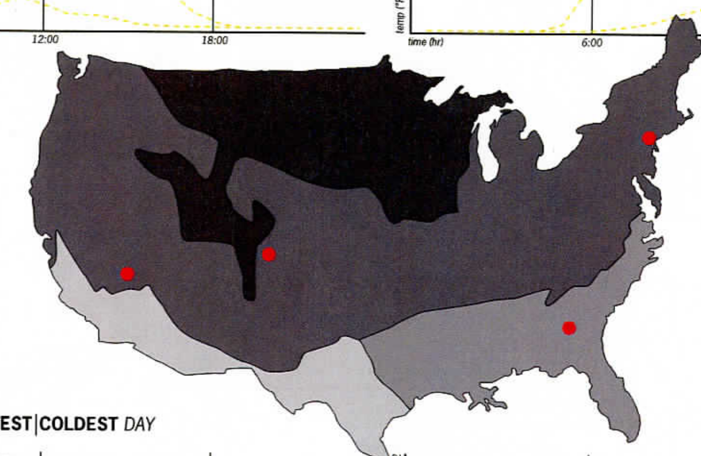
Regional Assembly Performance

The next critical step was to understand the potential climates in which the assembly was most appropriate. I ran models of the assembly in cities that fall into the four climatic regions of the United States. This became a critical piece of evidence that reinforced the fact that one assembly is not the appropriate choice for every place in America



Denver, CO

*asserting **critical regionalism** requires appropriate material decisions based on regional performance*

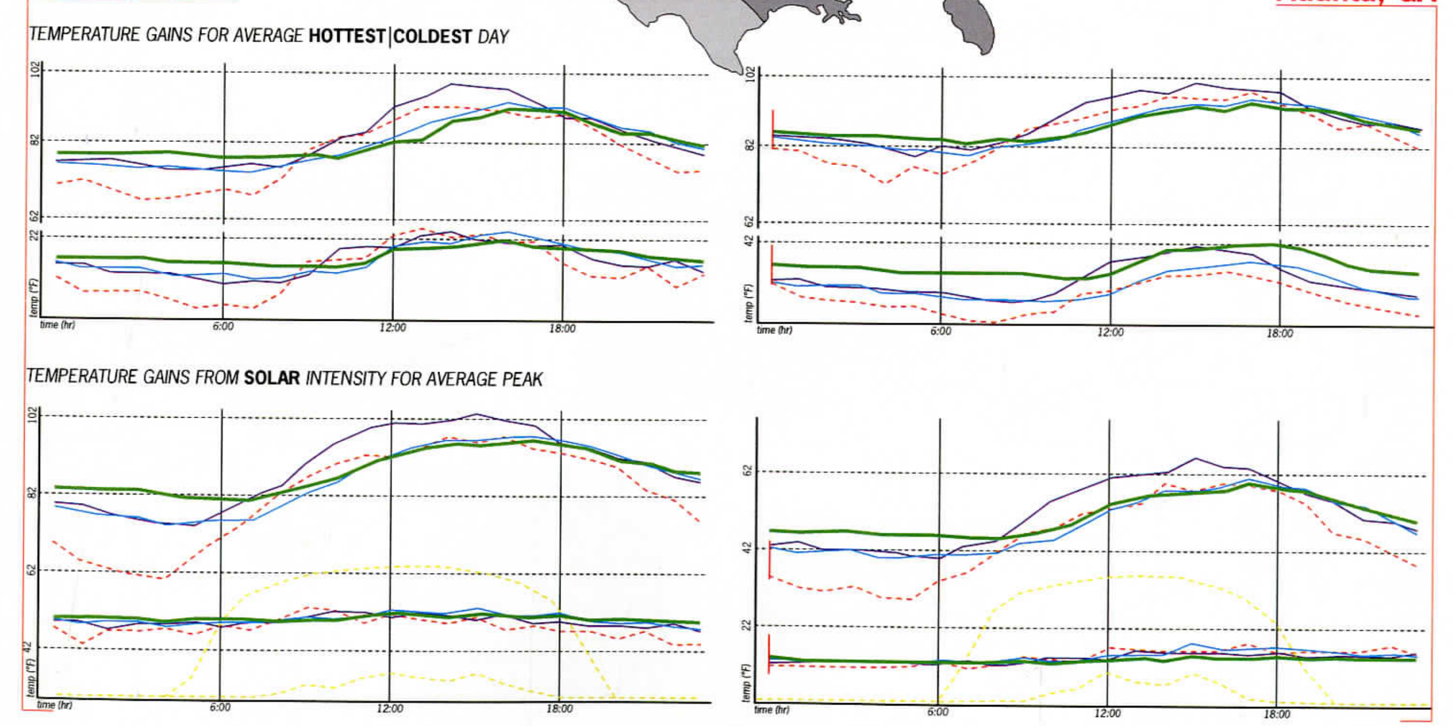


New York, NY

american climatic regions
- cool temperate
- temperate
- hot humid
- hot arid

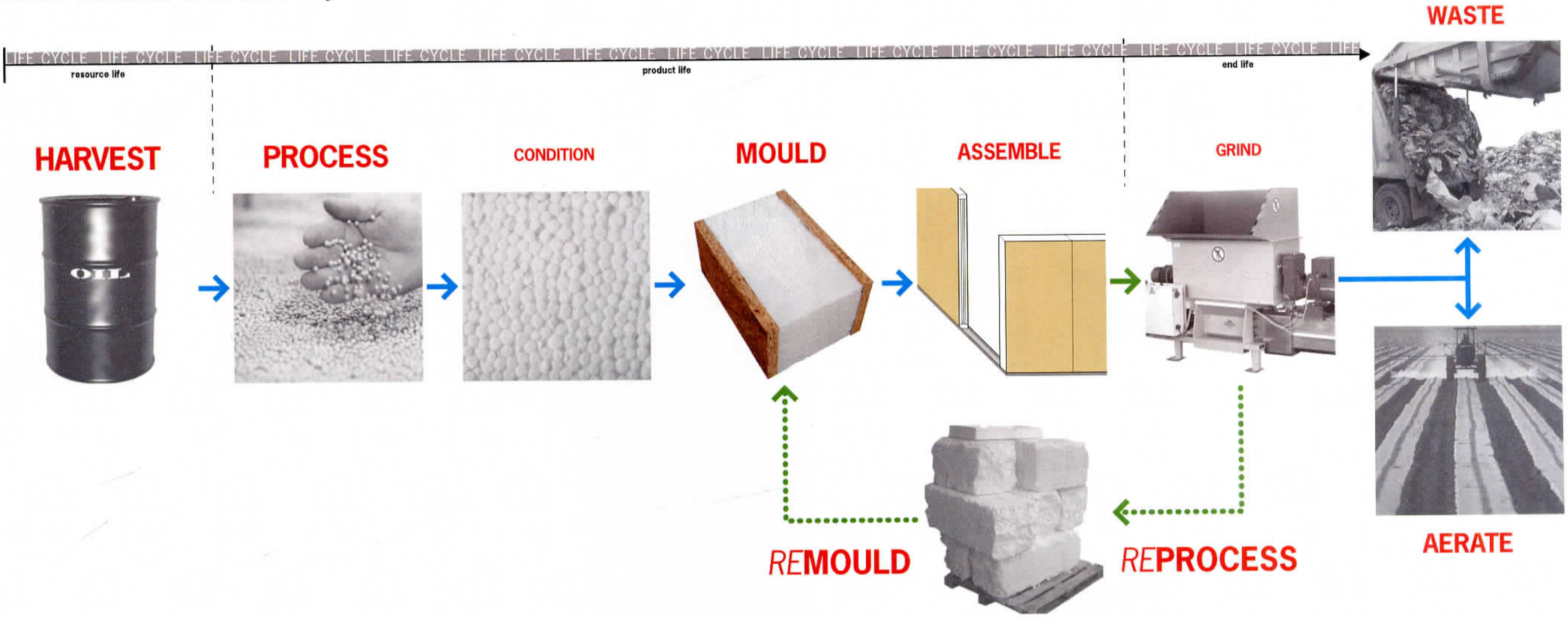
Las Vegas, NV

Atlanta, GA



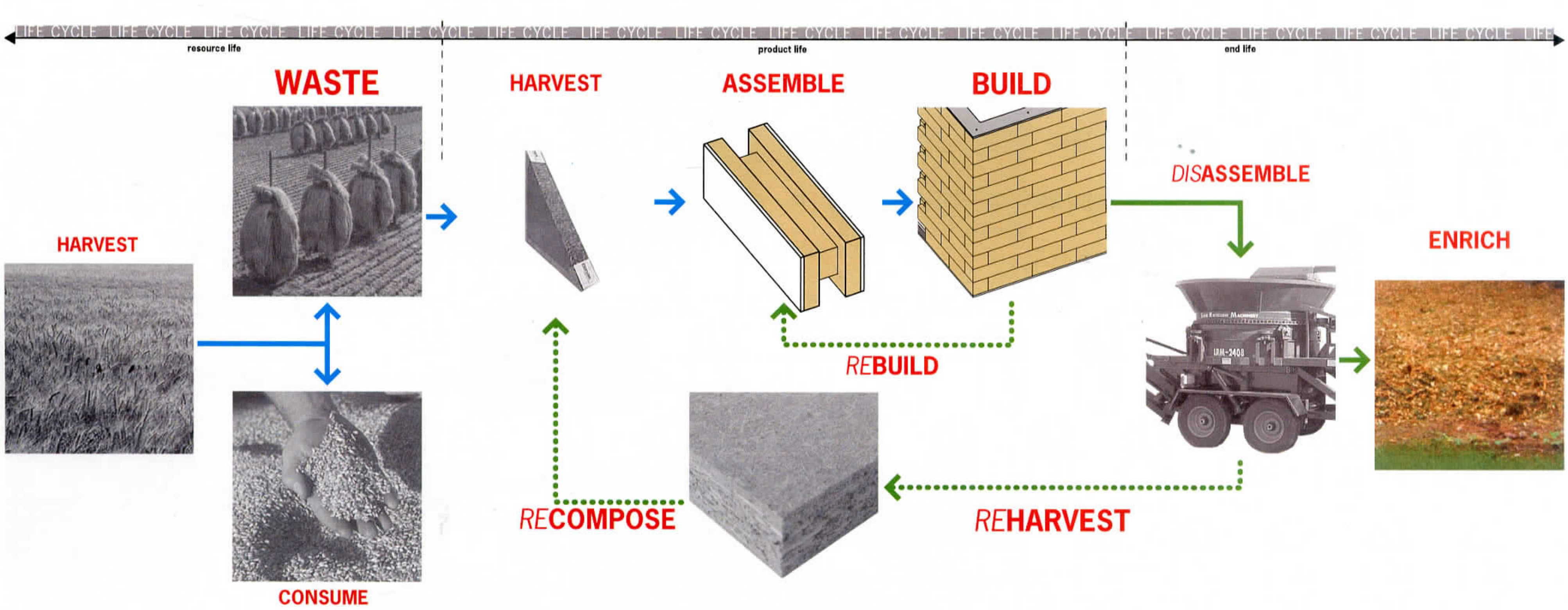
Extruded Polystyrene SIP Life Cycle

Life cycle comparisons are vital to illustrating the wider impact material production and use have on the environment. The analysis can become a productive tool for making material decisions and how to design with cradle to cradle materials in an assembly.



PROCESS_pentane gas exposed to oil polymers form polystyrene CONDITION_polystyrene beads expanded under steam MOULD_expanded polystyrene are steamed into product moulds ASSEMBLE_eps core modular sip panels GRIND_modular units can be separated for polystyrene recycling REPROCESS_ground eps pellets can be infinitely reused REMOULD_new products made from recycled eps WASTE_eps will never decompose but promotes aeration and waste decomposition in landfill AERATE_particles used to protect and promote crop growth

Sustainable Modular Unit Life Cycle

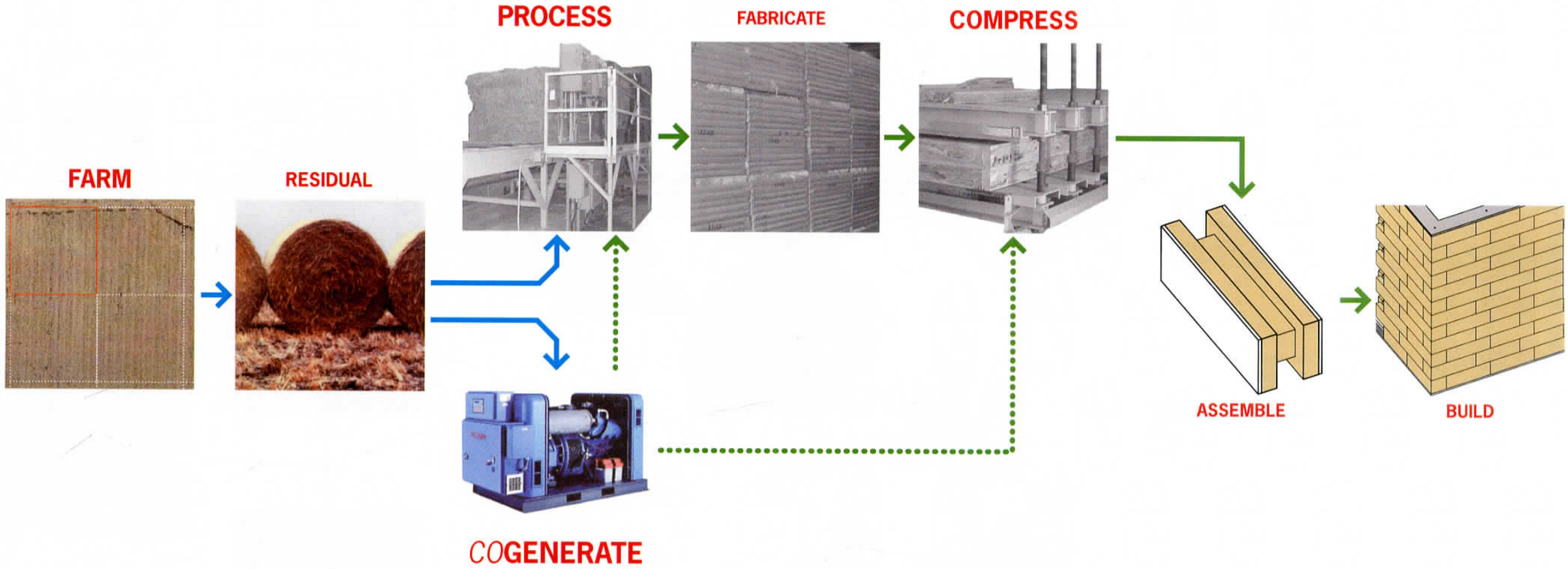


HARVEST_wheat and rice for consumption WASTE_unusable agri waste remains to be burned HARVEST_waste becomes primary material for agricore panel ASSEMBLE_combine parts into modular unit BUILD_join units into sustainable assembly REMOVE_disassemble units for reuse DISASSEMBLE_grind into new raw material REHARVEST_collect recycled waste RECOMPOSE_create new material from recycled content REUSE_material component in modular unit REBUILD_new uses as sheathing and finish ENRICH_decompose as mulch and fertilizer

(SELF) *Sustaining Production Model*

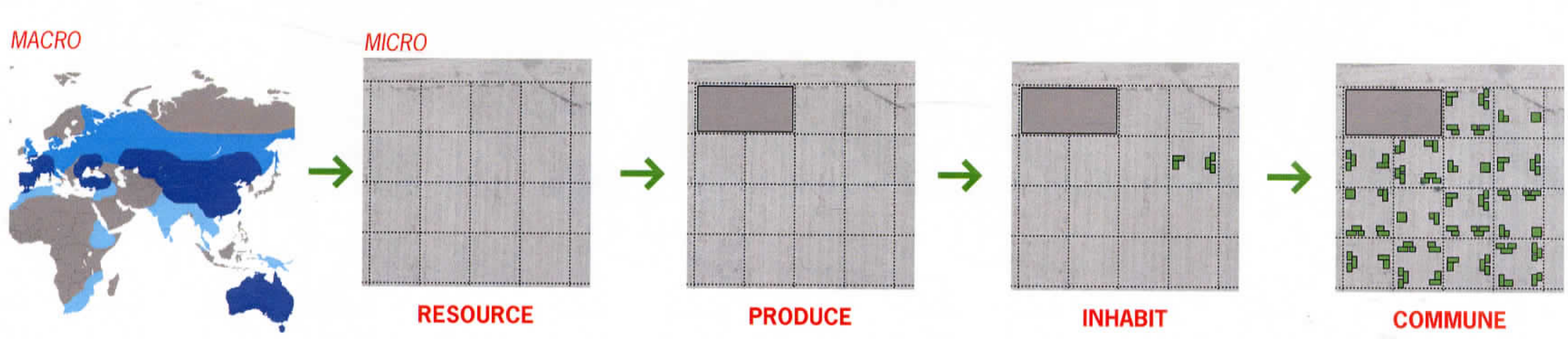
On a macro level the production process for a straw panel requires only compression and heat. This allows production of panels to occur almost anywhere there is a large agricultural base. The combustions of additional straw could run cogeneration machinery that would harness the heat and produce electricity that could run an entire production facility, while yielding no pollution. Making it a completely sustainable production process.

one acre ~ 200' x 200' ~ one bale | one bale ~ 900 lbs | combustion = electricity + heat | 150lbs per panel = 6 panels | compression + steam = panels | panel + osb = assemblies



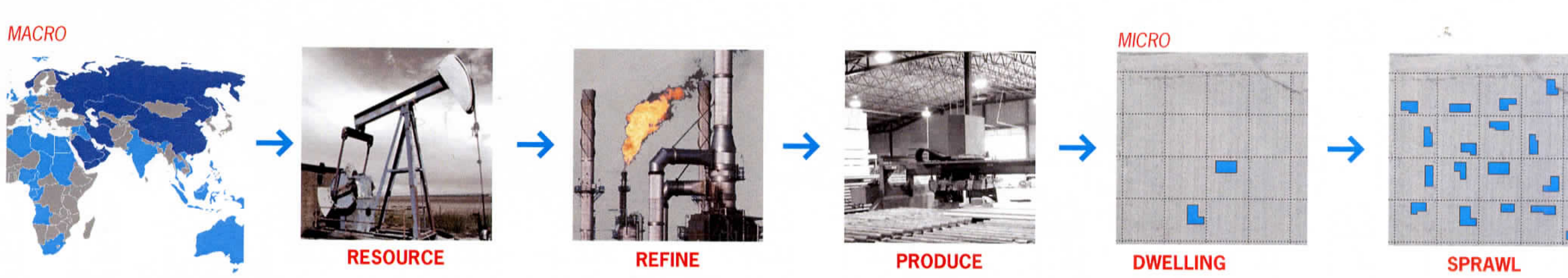
1 acre = 1 bale = electricity + heat   **1 bale = 6 panels = assembly = dwelling = commune**

(Self) *Sustaining Building Model* | SMU



MACRO_manufacturing can exist in any location with stable grain production production can be a completely sustainable and local process requireing little infrastrcutre MICRO_low impact local manufacturing provide dwellings for developing populations INHABIT_simple and modular consturction creates sensible building for local inhabitants RESOURCE_renewable by product from grain farming requires no additional processing COMMUNE_dense communites can develop adjacent to farmign and material production PRODUCE_

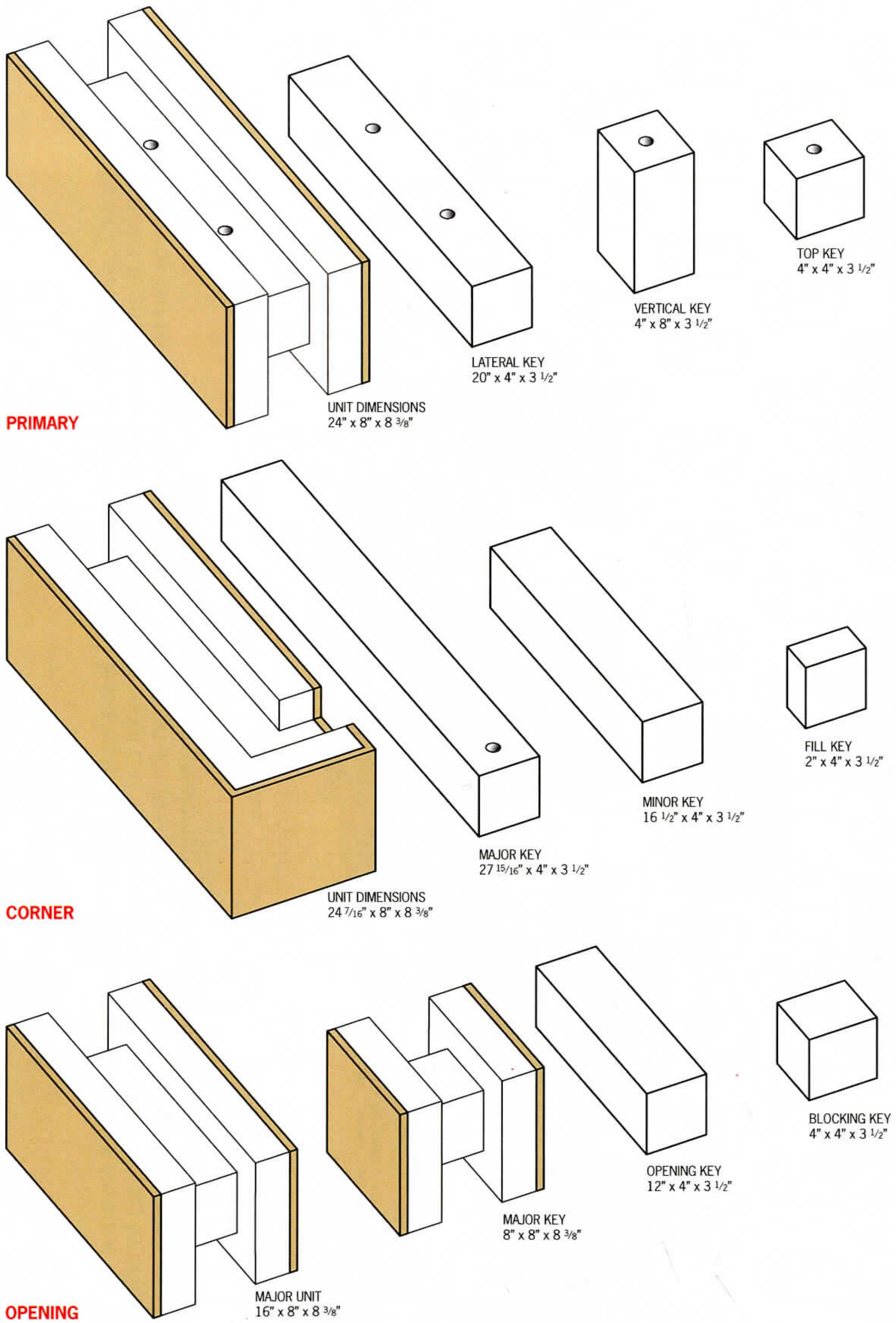
(Non) *Sustaining Building Model* | SIP

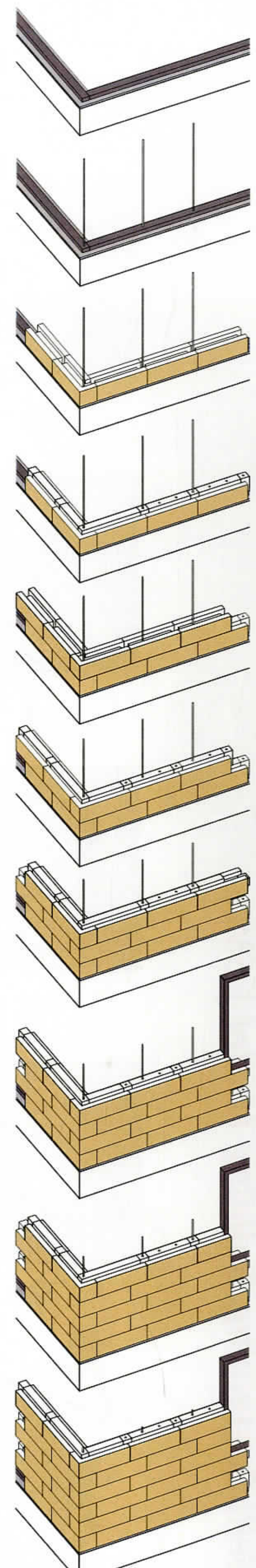


MACRO_resource requirements limit manufacturing possible locations MICRO_building units sent to building site typically outside industrial area RESOURCE_non renewable resource requires intesive extraction REFINE_styrene extracted through refinement DWELLING_rapid assembly and dynamic properties afford oversized building PRODUCE_manufacturing requires proximity resource and generally far from building siteto large industrial infrastructure SPRAWL_oversized building promotes poor land management

Sustainable Modular Unit Assembly Components

The most effective way to increase construction efficiency is with a modular, open, easily assembled system. The designed system, "the smu," standing for sustainable modular unit, is based on a block 2' by 8.375" that stack upon themselves and are joined together with a series of interlocking straw keys.

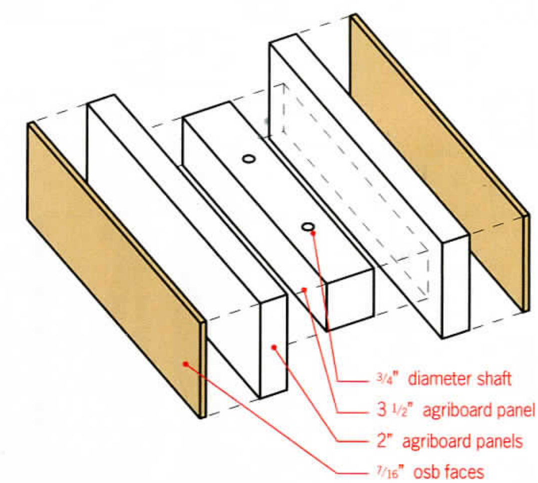




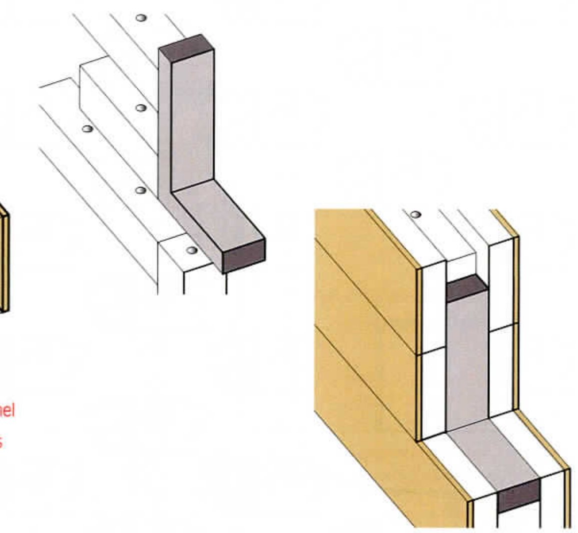
SMU Anatomy

The unit is composed of two 2" panel around a 3.5" core that is sheathed in osb. Each unit interlocks on all sides with the adjacent unit providing a thermal redundancy that cuts down on infiltration, drastically improving thermal performance. The unit itself weighs approximately 20 pounds and is light enough for one person to put in place and secure.

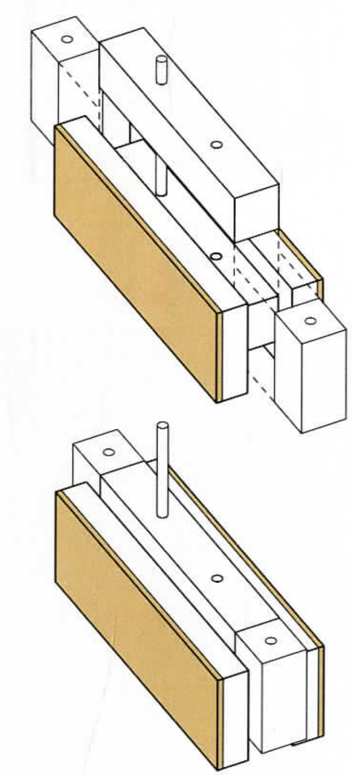
PRIMARY UNIT



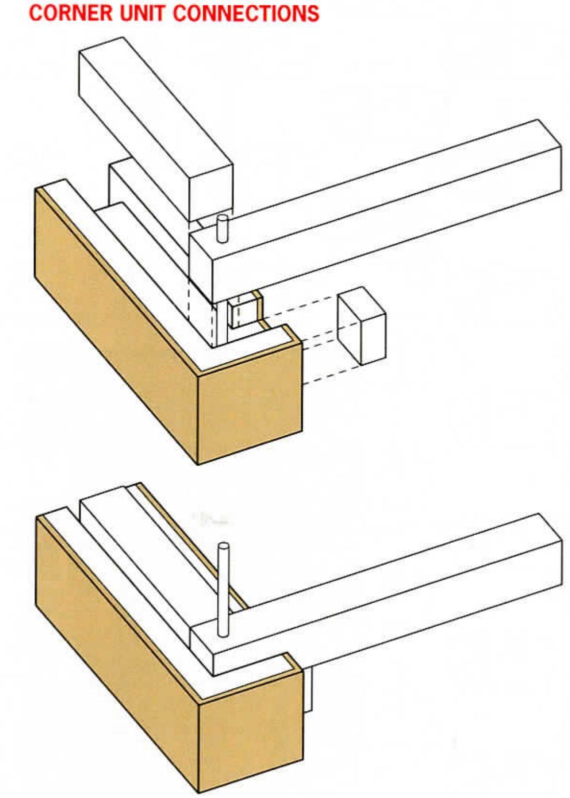
OPENING CONNECTIONS

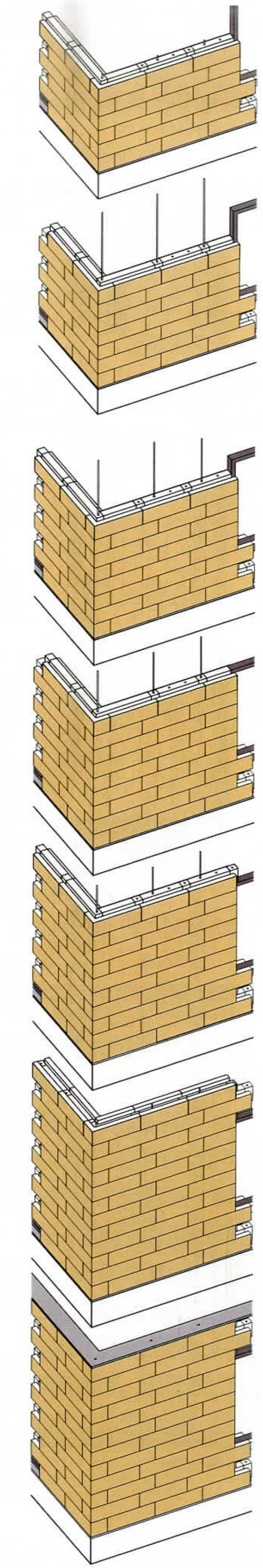


PRIMARY UNIT CONNECTIONS



CORNER UNIT CONNECTIONS

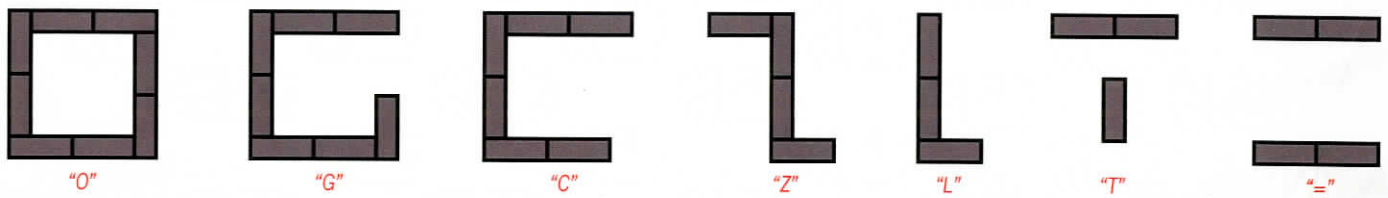




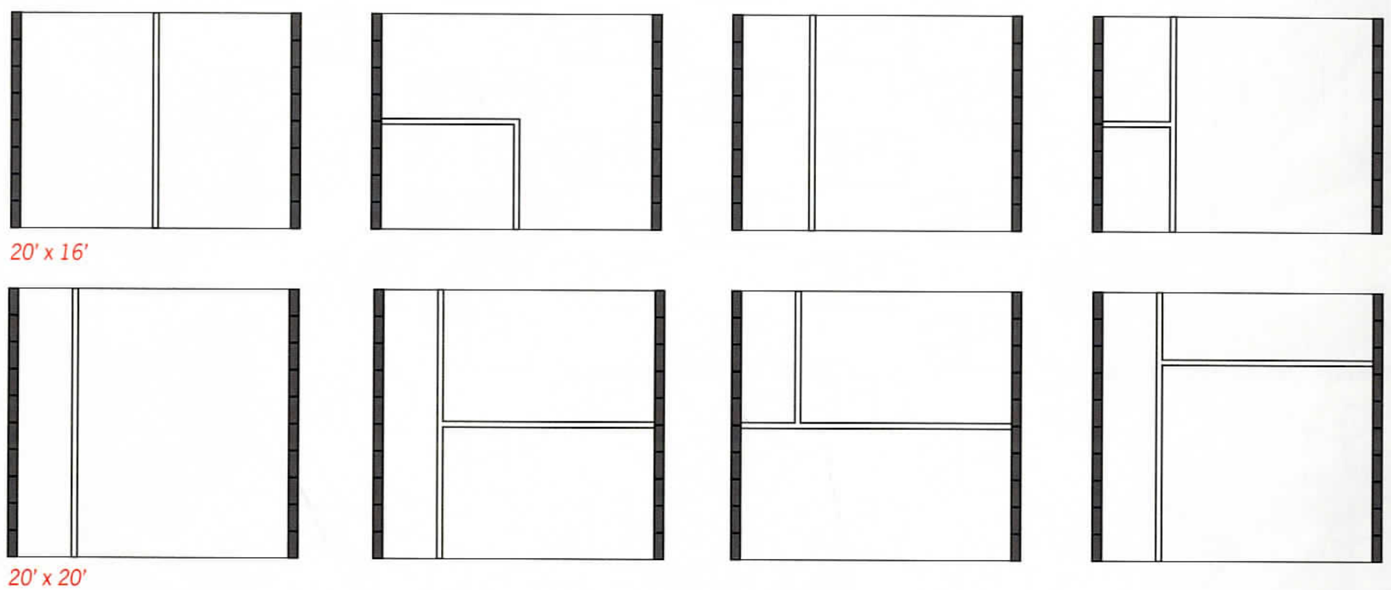
SMU Configurations

The 2' module allows for a series of standardized openings of 2' 4' 6' etc. Each assembly is a predetermined kit of parts, only 12 components are necessary to create an entire wall in a variety of layouts.

PRIMARY FORMS

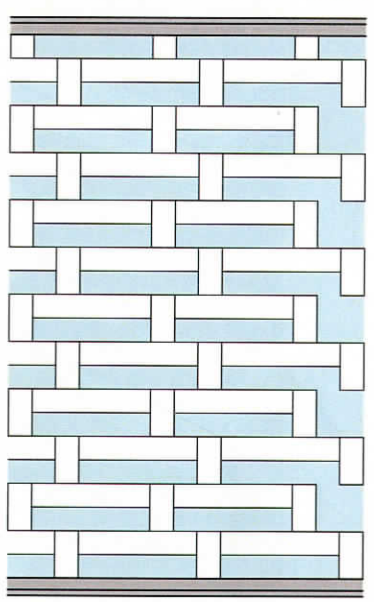


PLANAR PARAMETERS

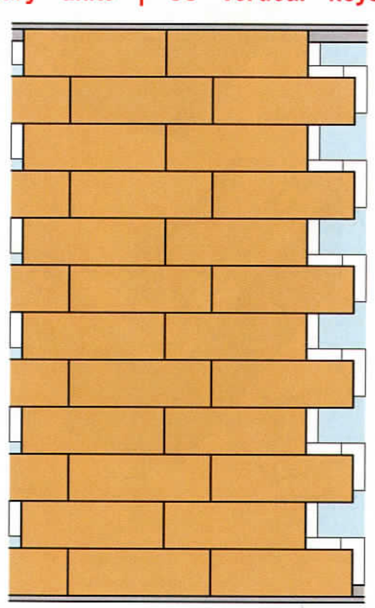


Elevation Framework

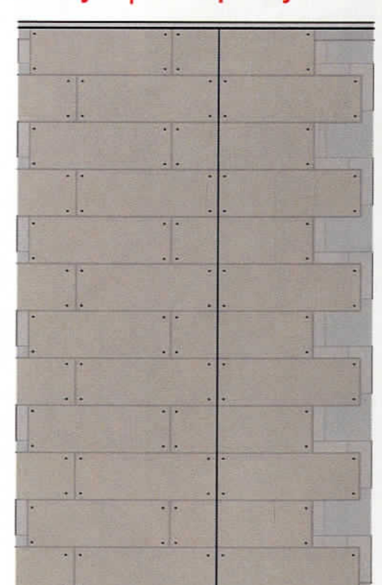
typical 4' x 8' section | 24 primary units | 33 vertical keys | 22 lateral keys | 3 top keys



sub structure



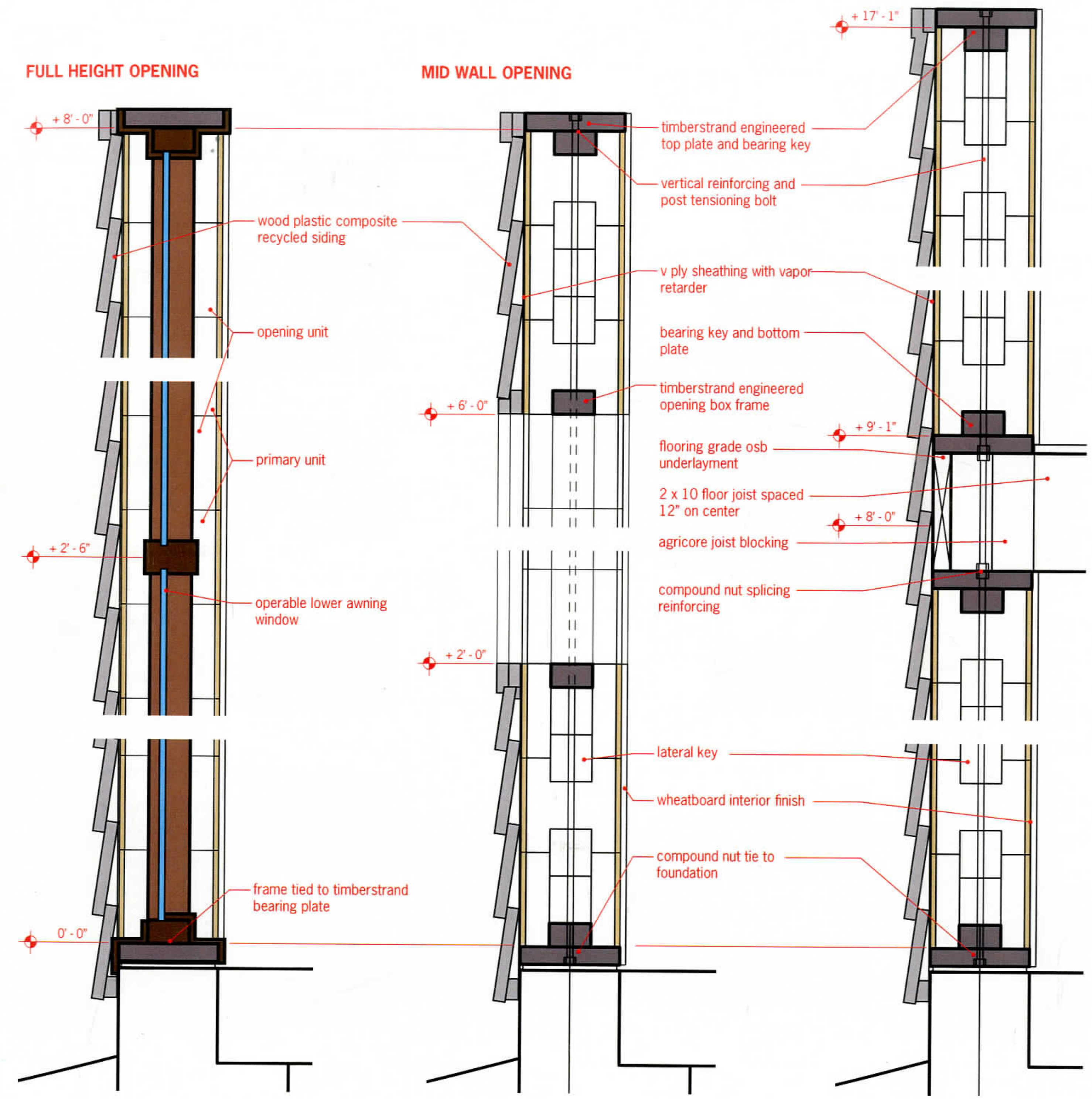
primary units



sheathed and moisture protected

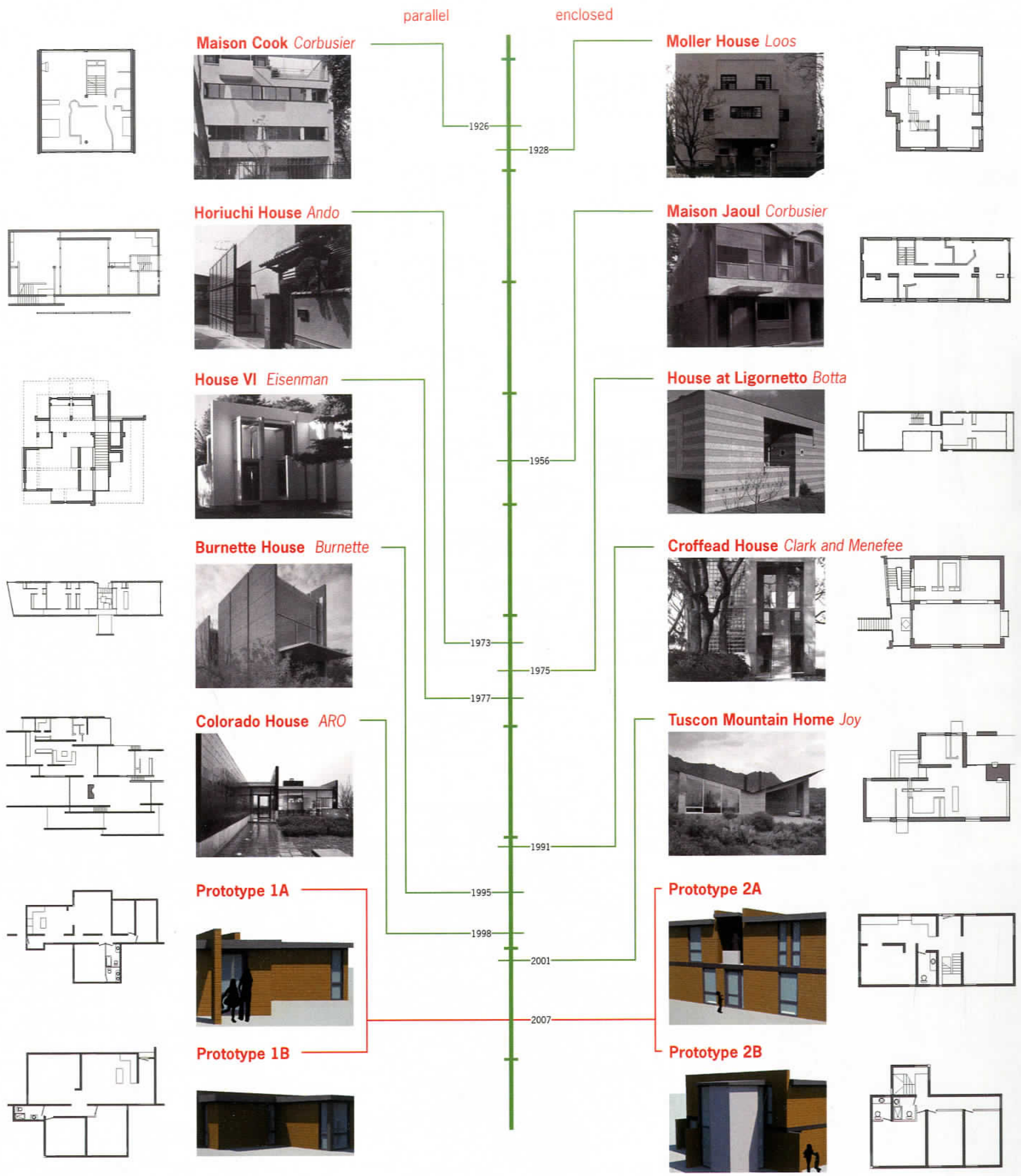
SMU Wall Section

The system requires threaded reinforcing at critical intervals to ensure lateral stability and combat uplift. Post tensioning the system to better seals any gaps in the assembly. The opening framing and floor framing connections intersect the top bearing plate. The bearing plate and box opening frame would be made form timberstrand engineered lumber, a recycled lumber product



Emerging Typologies

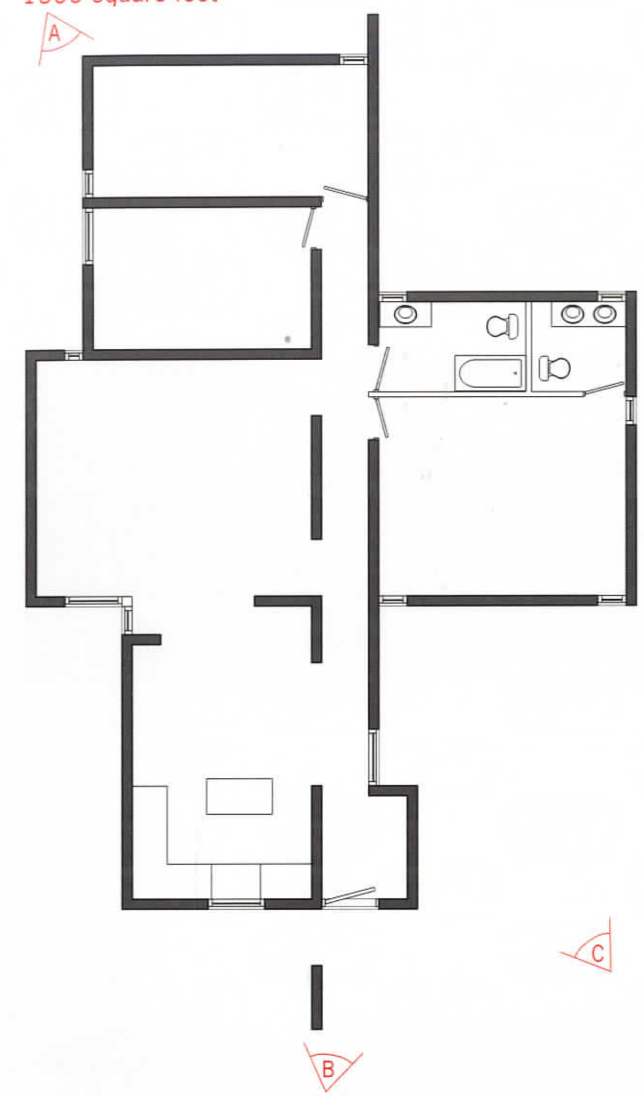
WALL AS BUILDING | BUILDING AS



Series One Prototype

Prototype OneA

1500 square feet



View A

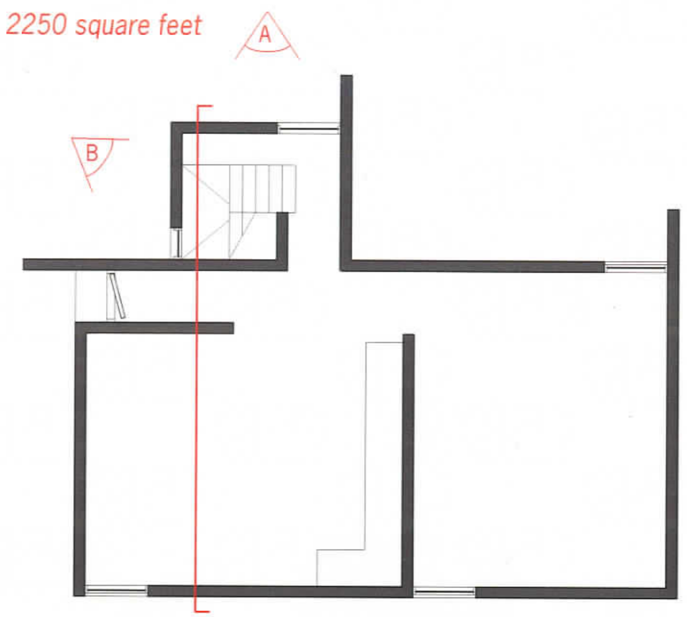
View B

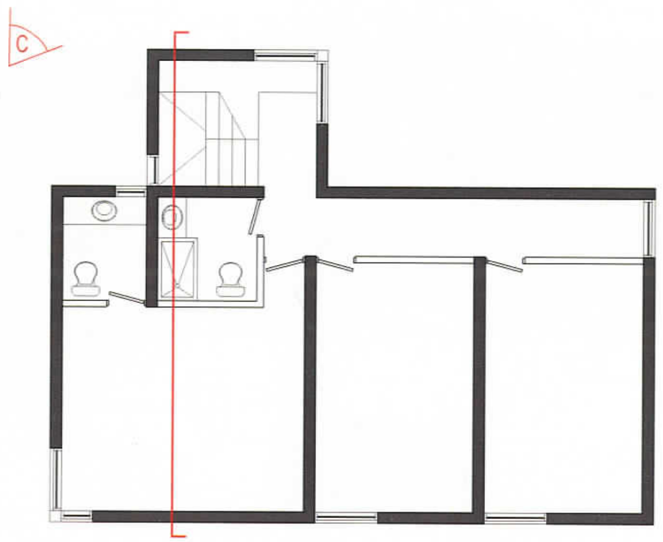
View C

Series Two Prototype

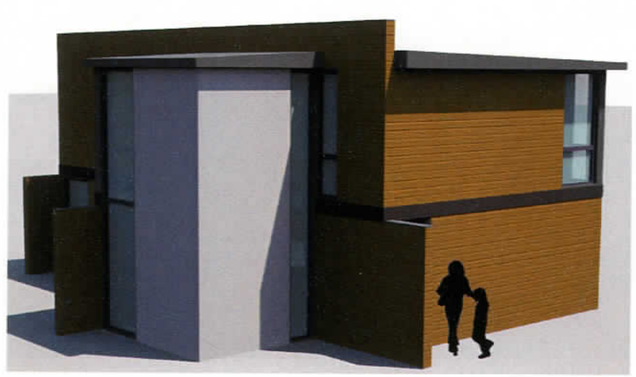
Prototype TwoA

2250 square feet





View A



View B

View C

Conclusion

Sustainability is more than adding or removing selected environmentally negative elements from an architectural design. It is a bottom up process that involves making informed, critical decisions about material choices based on their environmental impact, thermal performance, and appropriateness.

The smu assembly represents an opportunity to design and build residential structures, efficiently, economically, and without environmental impact.

Designing a residence based from a defined set of sustainable components, reasserts the performance of the building envelope and provides a new medium for climate specific vernacular architecture.